1.1.4.3 Alaskan Beaufort Sea

Ice conditions along the western approach to the Beaufort Sea are shown in Figure 1.1-19. Year round navigation along the Alaskan Beaufort coast largely depends on the degree to which the dominant, recurring east-west lead systems near the 30 m isobath can be safely used. Compared to the Bering and Chukchi seas, there is a much higher probability of encountering significant old ice concentrations in these waters. Mean concentrations of old ice are highest (about 3/10ths) between Point Barrow and Harrison Bay (Dickins, 1979), while during one in ten years, multi-year ice concentrations have reached 8/10ths in certain waters between Point Franklin and Prudhoe Bay (place names are shown in Figure 1-1). With few exceptions, the minimum old ice concentrations are encountered close to shore.

Level first year ice in the Alaskan Beaufort Sea reached a maximum thickness of 1.8 m (Dickins, 1979). Ridging is most severe between 20 and 80 km from the coast, and generally increases from west to east from an average frequency of 3/km at Point Barrow to over 7/km at Barter Island. Mean ridge heights range from 1.2 m in December to 1.7 m between February and April (Tucker et al., 1979). Open water duration in the Alaskan Beaufort Sea ranges from a minimum of 35 days off Prudhoe Bay to about 50 days elsewhere, and is generally limited to the period from mid August to early October. There is a large annual variability in the open water season in this region, depending on proximity of the polar pack to shore and prevailing winds. Even in mid winter, there is a high probability of encountering leads or thin ice zones paralleling the coast. The chance of encountering leads generally ranges from 40% in February to over 60% in May (Dickins, 1979).

The presence of cycles in ice severity off Alaska has been well documented (Barnett, 1977; McLeod and Hadden, 1977). Generally, these studies have shown unfavourable summer conditions (minimum open water with the ice pack closest to shore) in one of five years with the most favourable years being followed immediately by a winter of high multi-year ice concentrations.

1.1.4.4 Chukchi Sea

The Chukchi Sea is normally characterized by greater than 8/10ths first year ice during the winter, with a maximum thickness ranging from 120 cm in Kotzebue Sound to over 160 cm off Wainwright (Tucker et al., 1979). Multi-year ice concentrations increase from south to north, although winter means remain less than 2/10ths. Maximum old ice cover ranges from less than 4/10ths in the south to over 8/10ths north of Wainwright (one year in ten). There is a predominant winter flaw lead at the landfast ice edge between Cape Lisburne and Point Barrow.

As indicated in Figure 1.1-19, the normal open water season varies from 140 days (mid June to early November) in the south to 75 days at Point Barrow (early August to mid October in the north). However, recurring winter polynyas off Point Hope leads to an anomaly in the Cape Lisburne to Icy Cape area, with an average of 167 days of open water occurring between late May and early November. Extensive shear ice ridge fields are also common along the landfast ice edge in the Alaskan Beaufort.

The Chukchi Sea is a less dynamic but more highly pressured ice region than the Bering Sea. Laser profiles completed in the Icy Cape and Wainwright areas show mid winter ridge frequencies of 3 to 10/km, with mean ridge heights up to 1.6 m, peaking in the vicinity of the 30 m isobath (Tucker et al., 1979). Ridge frequencies are considered highest in the southern Chukchi Sea, although there are no publicly available quantitative data to confirm this.

1.1.4.5 Long Term Climate Change

The annual variability in the area of open water in the southeastern Beaufort Sea has been described in Section 1.1.3.4; measurements and observations of ice variables for shipping corridors are covered in Section 1.1.4. From these descriptions, it is not possible to determine future trends; the time series of observations is too short. Long time series, as far back as 10,000 years, have been obtained from cores extracted from the Devon Island Ice Cap and from Agassiz Ice Cap of Northern Ellesmere Island. These have been analyzed by Koerner and Fisher (1981) of the Polar Continental Shelf Project.

Koerner and Fisher predict a "High Arctic" annual "natural" temperature cooling of between 0.5 and 1.0°C between now and the year 2010. A similar short term natural cooling trend is supported by other investigators based on Camp Century cores from Greenland. Although the cores reflect past climate in locations within 500 km of each other, it is likely that predictions encompass the High Arctic Islands, the Northwest Passage and possibly the southeastern Beaufort Sea. The annual cooling trend prediction is based only on expected natural changes and excludes possible man-caused changes such as the effects of increasing carbon dioxide (CO_2) concentrations in the atmosphere. Indications are that man-caused atmospheric heating and atmospheric dust do not result in significant climate change; however, more serious are possible CO_2 effects.

So far, no evidence of CO_2 caused climate change is apparent in any climate record. However, recent numerical models dealing with possible CO_2 effects

on the long term world's climate have reached a level of sophistication that their predictions cannot be dismissed (for a review see Hare, 1981). Most of these models predict climatic warming based on a constant natural climate. World average atmospheric temperatures are predicted to rise as much as 2.5°C over the next 50 to 70 years. These CO_2 caused temperature rises could emerge from the "noise level" of climate records by the year 2000. If such predictions on possible CO_2 effects prove to be true, then they would likely compensate for part of or more than the natural cooling in the High Arctic predicted by Koerner and Fisher (1981).

On the other hand, if man-caused CO_2 warming does not occur, a natural cooling prediction of 0.5 to 1.0°C over the next 30 years would produce increasing concentrations of multi-year ice in the summer, resulting from the increased survival of summer ice into winter. Koerner and Fisher (1981) have verified this effect because of the good relationship between the thickness of core melt-layers and observed amounts of open water in the Archipelago.

It is not certain that the natural cooling prediction applies necessarily to Arctic regions external to the Arctic Islands. Maxwell (1981) has used Arctic weather station records to classify climatic regions in the Canadian Arctic. Unfortunately his records from Cape Parry and Sachs Harbour are not long enough to show recent cooling or warming trends. Other stations, such as Alert Bay, Eureka, Resolute, Mould Bay and Isachsen, all in the High Arctic Islands, do, however, show a cooling of about 1°C since 1956, based on 10 year averages. These observations tend to support Koerner and Fishers cooling prediction for the High Arctic.

The conclusions are: that a high probability exists of a 0.5 to 1.0°C annual cooling taking place over the next 30 years in the High Arctic due to natural causes; that the predicted natural cooling does not necessarily apply to the Beaufort Sea region; that man-caused CO_2 atmospheric warming is predicted which could be detectable by the year 2000; and that the CO_2 warming, if real, could compensate for part of or more than the predicted natural cooling.

1.2 SURFACE WEATHER AND WIND WAVES

The following section briefly summarizes available climatological information describing temperature, Arctic temperature inversions, precipitation, visibility, winds, wind waves and synoptic storm tracks in the Beaufort-Chukchi region. Since accumulation of ice on marine vessels and offshore installations can be hazardous in this region, structural icing is also discussed. More details on the regional climate are provided in a supporting document (MEP, 1981b), while the climatology and atmospheric environment of coastal areas of the Beaufort Sea are discussed in Section 2.1.

1.2.1 WEATHER AND WEATHER FORECASTS

Weather is the term used to describe current atmospheric conditions. Climate, on the other hand, describes average weather conditions to be expected based on a long history of weather observations. In the Beaufort region, weather information and weather forecasts are provided by the Beaufort Weather Office (BWO) situated at Dome Petroleums Tuktoyaktuk basecamp. The BWO is operated by the Atmospheric Environment Service and funded by both Dome Petroleum Ltd. and Esso Resources Canada Ltd.

The forecast support network comprises the Canadian Meteorological Centre (CMC) in Montreal, Quebec, the Arctic Weather Centre (ARWC) in Edmonton, Alberta, and Ice Forecasting Central (IFC) in Ottawa, Ontario. CMC provides wide-area and long-range forecasts as source data to IFC and the BWO. ARWC has two main functions. It provides an overview of factors affecting weather over northern Canada, and it provides the BWO forecaster with routine aviation, marine and public forecasts overlapping the BWO area of interest. Between approximately May and December, the BWO is staffed by a team of meteorologists. The Atmospheric Environment Services Ice Branch ice observers, who report on daily ice conditions throughout the open water drilling period, comprise additional seasonal staff.

The principal function of the BWO is to provide site-specific forecasts of winds, waves and ice during the drilling season. Forecasts are issued daily at 6:00 am and 6:00 pm with updates at noon and midnight supplemented by updates reflecting changing weather. During 1980, for example, up to eight site-specific forecasts were issued. Wind, ice and gale advisories are also issued.

Meteorological teletype circuits transmit data from most of northern and western Canada, as well as from parts of northern and eastern Alaska. A data link to the Atmospheric Environment Service (AES) computer centre in Edmonton introduces additional data from Alaska, Siberia, the High Arctic and the Pacific.

During 1980, air pressure data from over the ice pack became available from up to nine POLEX buoys during the latter part of the drilling season. These data were routinely available through the Edmonton data link (AES, 1980). Data are also provided by the

four nearby DEW-line stations at Komakuk, Shingle Point, Tuktoyaktuk and Nicholson Peninsula which issue short hourly reports in addition to their regular six hourly reports. These, combined with routine observations from the four Canmar drillships, one or two Esso Resources sites, and intermittent data from other ships and land-based sites, provide a close-knit supplemental data network.

1.2.2 CLIMATOLOGICAL DATA SOURCES AND LIMITATIONS

Historical weather data sources for the Beaufort-Chukchi region are primarily from coastal weather stations. Offshore data are from ships operating exclusively in the summer. There is a particular lack of wind data over the Chukchi Sea and comparatively, more historical data are available for the Beaufort Sea except over the pack ice.

The two major information sources for this region are reports by Burns (1973) and Brower et al. (1977). Both sources use historical data to the years 1973 and 1974 only. Twenty-five years of coastal and Canadian mean data were analyzed along with U.S. marine data spanning the years 1972 to 1974. An additional source of summer meteorological data for the Beaufort Sea is information collected yearly (since 1976) from Dome Petroleum's drillships during the period July to October.

1.2.3 TEMPERATURE

Extremely low temperatures can reduce human health and activity, and make equipment difficult to operate. Wind chill results from the combined effect of low temperatures and wind. Human heat loss increases dramatically as either the wind speed increases or the temperature decreases beyond a critical threshold. The combined effect of wind speed and air temperature on exposed flesh, which is known as wind chill, is illustrated in Figure 1.2-1.

Figures 1.2-2 and 1.2-3 show the mean air temperatures for the Beaufort-Chukchi region during February and August, respectively (Brower et al., 1977; Maxwell, 1980). Greater detail on seasonal differences in mean and extreme temperatures recorded at various coastal locations is provided in Section 2.1. The long Arctic winter is characterized by the Arctic Inversion (Section 1.2.4) and is often described as a season of "persistent" cold rather than "extreme" cold (Maxwell, 1980). Mean temperatures in the winter are -20°C for the southern Chukchi Sea and -30°C for the Beaufort Sea. Extreme minimum temperatures recorded in these two areas are -50.6°C at Barter Island and -50°C at Tuktoyaktuk, respectively. During the summer, mean temperatures increase to about 6°C on the coast and to about 2°C, 500 km offshore (Figure 1.2-3). Summer temperatures over open water are moderated by the heat exchange from the ocean to the air, resulting in strong horizontal temperature gradients perpendicular to the shore. Extreme maximum temperatures recorded were 30°C in the Beaufort at Tuktoyaktuk and 29.4°C in the Chukchi at Kotzebue (Burns, 1973; Brower et al., 1977).

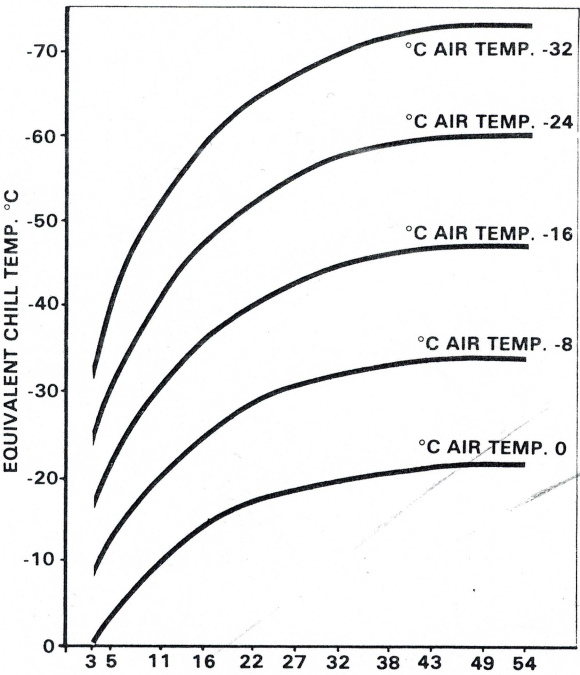

FIGURE 1.2-1 *Wind chill factors. Wind chill results from the combined effect of low temperatures and wind.*

During the autumn, before freeze-up, the sea is a source of heat so that temperatures over the water are often warmer than those over nearby land (Burns, 1973). This seasonal difference causes land-sea breezes. Also, "steaming" of the relatively warm ocean water adds moisture to the air. Ice begins to form on the sea in autumn as the air temperature decreases below freezing. Once the ice thickness exceeds 0.3 m there is little heat exchange between the water and air, and air temperatures over the ice pack drop rapidly.

Meteorological records collected at onshore stations show little diurnal variation in temperature. The maximum daily temperature range of about 10°C occurs in July, while the minimum range of less than 4°C occurs in August or early September. Over open water, air temperatures are strongly influenced by temperatures of the upper water column.

1.2.4 THE ARCTIC TEMPERATURE INVERSION

Normally the air temperature decreases with height. If this temperature decrease exceeds that due to the